

## Oil Shale Resource in Mae Sot Basin, Thailand

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### *Abstract*

The largest oil shale resource in Thailand is found in the northern region in Mae Sot Basin, Tak province. It covers approximately 600 square kilometers. About 925.38 million tons of oil shale and 182.86 million barrels of shale oil are estimated by USGS 891 method.

Mae Sot Basin lies in NW-SE direction. This basin consists of 2 sub-basins (1) the northern sub-basin and (2) the southern sub-basin. The bedding of the oil shale layer dips 5-25° in the west. The oil shale in the northern sub-basin is shallower than in the southern sub-basin. However, the oil shale layer in the northern sub-basin is thicker and more continuous than the southern one. The potential yield of oil in the northern sub-basin is also higher than the southern sub-basin.

The quality of the oil shale in general is poor to medium. According to Modified Fischer Assay method, the estimated oil yield varies from 1-26% by weight or about 2.5–65 gallons/ton. The average of oil yield is about 5% by weight or 12 gallons/ton. The heating value is 700-4,000 kcal/kg. Ash, organic and shale residual are 56-70%, 10-24%, and 66-94%, respectively. The oil yield given from Kiviter retorting test is 15.22 gallons/ton oil yield, equivalent to 6.1% by weight. The shale oil consists of 84.66% carbon, 11.20% hydrogen, 1% nitrogen, 2.5% oxygen and 0.64% sulfur.

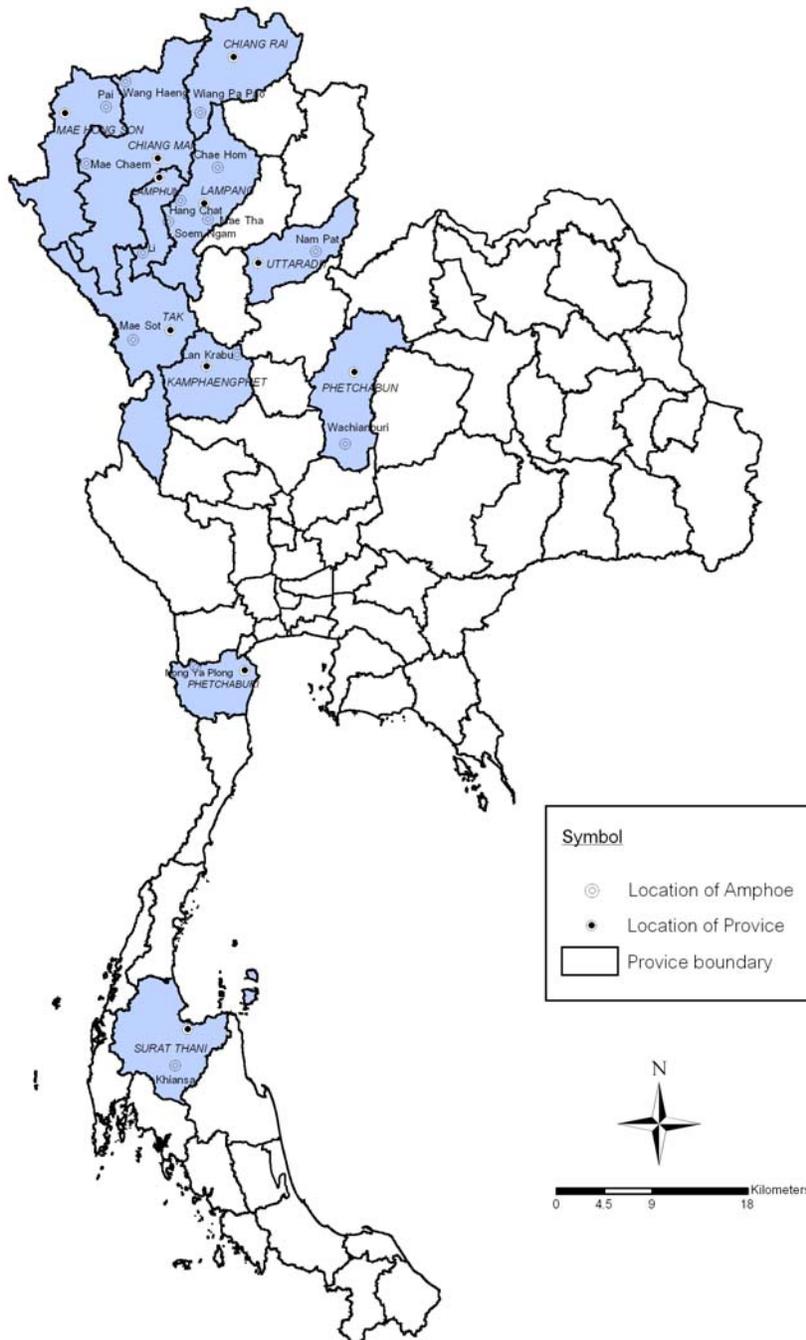
### *Introduction*

Thailand is a non-oil-producing country. Crude oil prices have increased throughout the world from 1994 to 2007. The crude oil price did not fluctuate much until 2003 when there was a dramatic increase of crude oil price from US\$30 per barrel to US\$90.83 per barrel on October 30, 2007. Moreover, the crude oil becomes economically non-viable because of depletion and scarceness of petroleum supply. As a consequence, alternative fuel sources must be found.

In Thailand, the government is looking for alternative fuel sources to produce oil or oil-substitute fuel. Oil shale is one of the most interesting alternative sources for producing oil because of its large reserve. The total reserve of oil shale is approximately 18.668 billion tons which can be used to produce around 810 million tons of

shale oil (Department of Mineral Fuel [DMF], 2007; Thanomsap and Sitahiran, 1989).

Oil shale deposits are widespread in many regions covering 11 provinces. There are 15 oil shale sources. Almost all of oil shale sources are distributed especially in Northern provinces of Thailand such as Mae Hong Son, Chiang Mai, Chiang Rai, Lamphun, Lampang, Kumpang Petch, Uttaradit, and Tak. The rest are distributed in the Southern province of Surat Thani, the North-Eastern province of Petchabun and the Central province of Petchaburi (Figure 1). The Mae Sot oil shale deposit is the largest oil shale resource. It is located in Mae Sot Basin, Tak province. The total reserve of Mae Sot oil shale is approximately 18.668 billion tons, which is equivalent to 97.3% of the overall oil shale reserve in Thailand (Thanomsap and Sitahiran, 1989).



**Figure 1:** Distribution of Oil Shale sources in Thailand

The Mae Sot oil shale source has been explored several times, starting in 1935 by Swiss and Japanese geologists. In 1947, the Department of Mineral Resources (DMR) commanded an exploration to evaluate oil shale reserve in the area. Then, many other agencies followed. They

included National Policy Office, the Military Energy Office, the Electricity Generating Authority of Thailand and the Department of Geological Science, Chiang Mai University. In 1982, Germany and the Japanese government financially supported a study of the feasibility of commercial utilization of oil shale.

Since then, activities were delayed for many years, until 1996, when the Mineral Fuels Division of the Department of Mineral Resources proposed a project on evaluation of the development and utilization of oil shale in Mae Sot Basin.

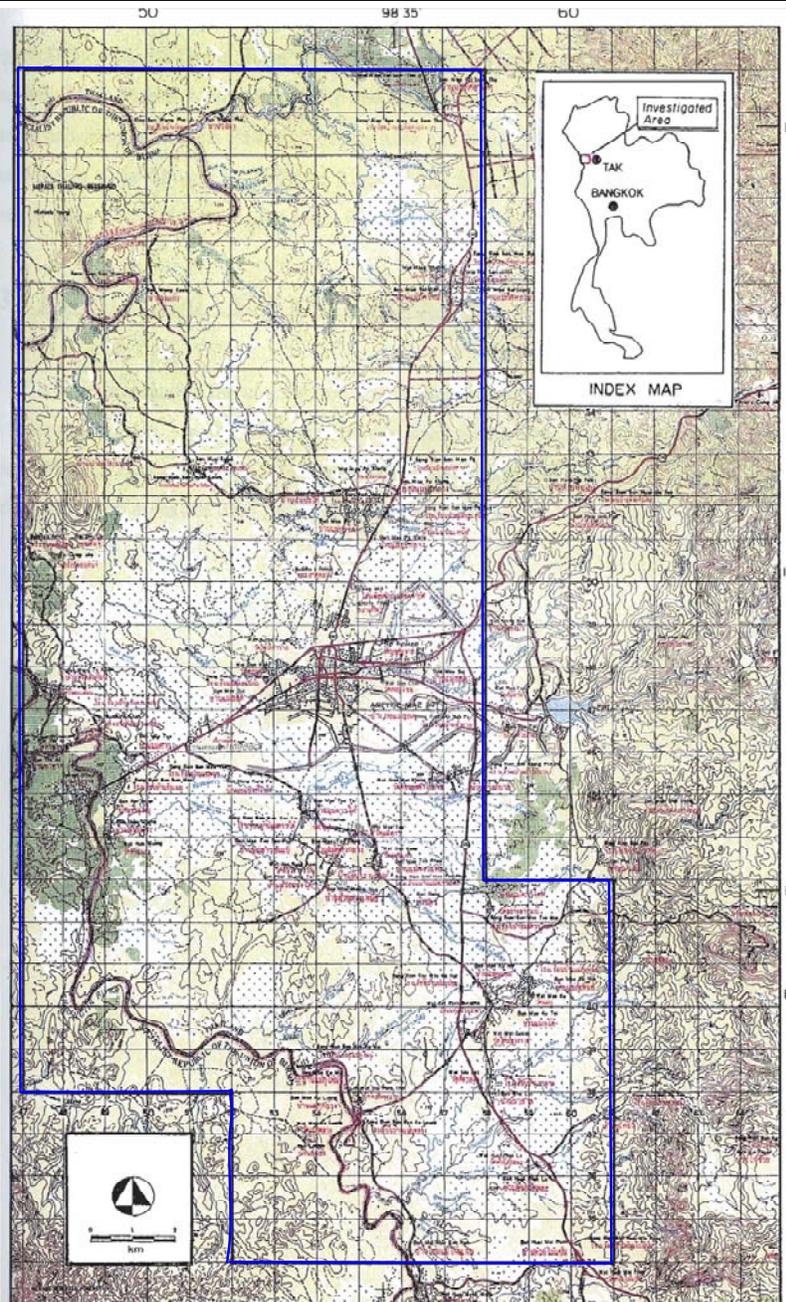
*Location*

The Mae Sot Basin is located at Mae Sot district and Mae Ramart district in Tak. It is close to the boundary between Thailand and Myanmar. The Moei River flows from south to north, acting as an international boundary. The Mae Sot Basin covers approximately 600 sq km, and is 55 km long and 15 km wide (DMR, 1997). About 67% of the Mae Sot Basin is in Thailand and the rest is in Myanmar.

The investigated area of DMR project in 1996 is in the middle part of Mae Sot Basin, covering 315 sq km, as shown in Figure 2.

*General characteristic of Mae Sot Basin*

The large Mae Sot Basin is composed mainly of colluvial and alluvial plains, with some small hills of about 200 m-MSL.



**Figure 2:** The Topographic map of investigated area in map sheet 4742 III and 4742IV

Mae Sot Basin consists of 2 sub-basins, the Northern sub-basin and the Southern sub-basin (Figure 3). The Southern sub-basin covers 250 sq km. Mae Sot Basin lies in a NW-SE direction. The northern sub-basin is shallower than the southern sub-basin. The

direction of oil shale bedding dips in west about 5-25°. The oil shale layer is exposed at the surface in some areas in Mae Sot Basin (Thanomsap and Sitahirun, 1992).

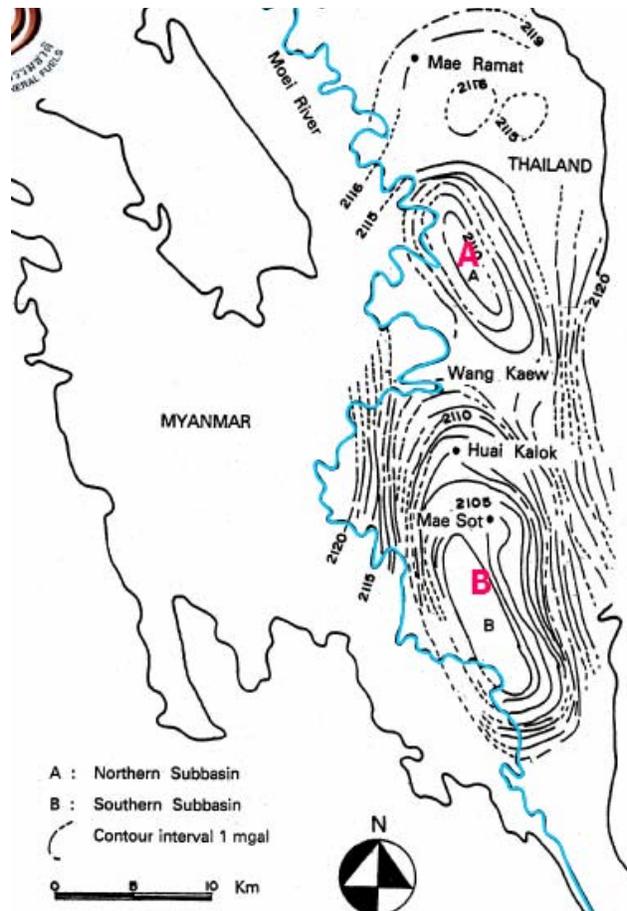
Oil shale deposits in intermontane Tertiary basin consist of shale, marlstone, sandstone, conglomerate sandstone and limestone. The environments of deposition can be classified into 2 types: Fluvial and Lacustrine (Thanomsap and Sitahirun, 1992).

Based on drilling data, the stratigraphy of Mae Sot Basin consists of three formations (Thanomsap and Sitahirun, 1992). From lower formation to upper formation these are: Mae Ramat Formation, Mae Pa Formation, and Mae Sot Formation.

Mae Ramat Formation, the lowest formation, comprises sedimentary rocks deposited along the alluvial plain and in alluvial fans. The rocks consist of conglomerate, sandstone, limestone, siltstone and mudstone, unconformably overlying pre-Tertiary rocks. This formation is approximately 240m thick and is assigned to the Paleocene by Braun and Jordan (1976).

Mae Pa Formation is the middle formation between Mae Ramat Formation and Mae Sot Formation. The rocks comprise two units of sedimentary rocks

that were deposited in lacustrine and fluvio-lacustrine environments. They consist of pisolitic limestone, peloidal rocks, fossiliferous limestone rock of the estuary, channel and shore. They are found at the border of the southern basin.



**Figure 3:** Mae Sot Basin consist of 2 sub-basins (A) Northern sub-basin and (B) Southern sub-basin

Mae Sot Formation is found in the middle part of the basin. It can be divided into two units:

1. Sandy shale, sandy marlstone, silt claystone interbedded with oil shale. The oil shale beds vary between 3 and 5m thick, and may be more than 10m thick in some areas. These rocks were deposited in the fluvio-lacustrine environment. They are found in the western and northern part of basin covering Ban Mae Pa, Ban Huai Kaloke and north of Ban Mae Pa Thai.
2. Grey to greenish grey shale interbedded with mudstone and oil shale. The rocks were deposited in a lacustrine environment. They are found in the middle part of the basin from Ban Huai Kaloke to Ban Mae Ku Luang, with the total distance of 17km. The quality of

oil shale varies from low to high grade, with thickness over 30m in some areas.

From seismic interpretation (7 seismic lines in the Northern part of basin and 11 seismic lines in the Southern part of basin), the stratigraphy can be divided according to seismic facies into six units: Unit A, B, C, D, E and F (Figures 4 and 5) (DMR, 1997).

Unit F is the lowest detected unit. Its thickness is about 600m. This unit was deposited in barrier, channel and fluvial environments, in upper Oligocene. It can be correlated to middle part of Mae Pa Formation.

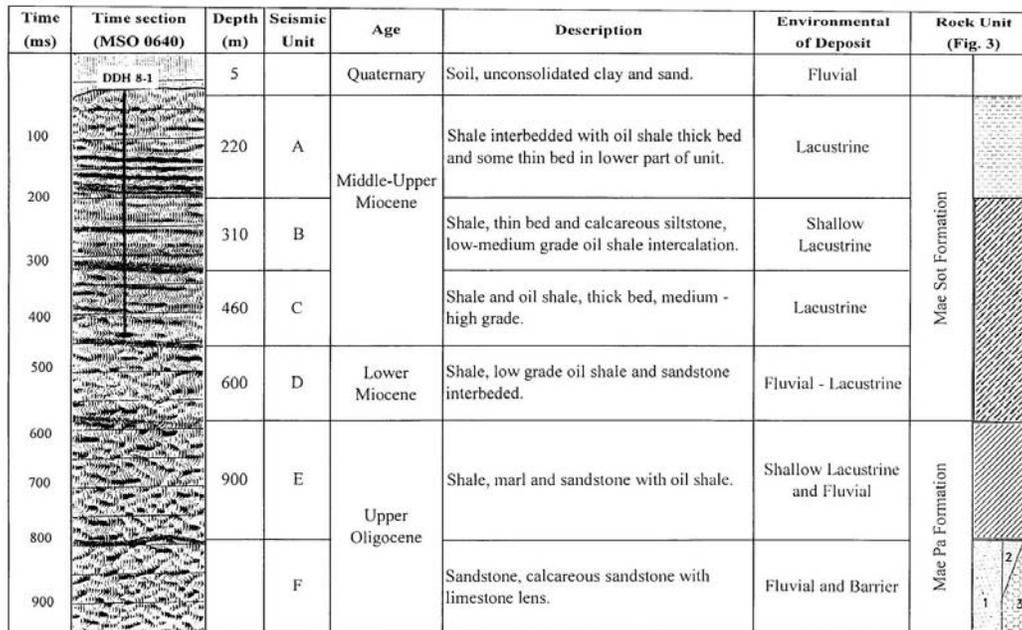
Unit E is composed of shale and marl interbedded with sandstone. Its thickness is about 500m. Oil shale may be interbedded in the middle part of the unit. This unit was deposited in shallow lacustrine and fluvial environments, in Oligocene-Lower Miocene. It can be correlated to the upper part of Mae Pa Formation.

Unit C consists of shale and oil shale. The thickness of this unit is about 250m. The oil shale bedding is thick; the quality of oil shale varies from medium to high grade. The age of Unit C, deposited in Middle Miocene, can be correlated to the upper part of Mae Sot Formation.

Unit B consists of shale and oil shale. Oil shale is low to medium grade. The oil shale is thin. This unit was deposited in a shallow lacustrine environment, in Middle-Upper Miocene and can be correlated to lower part of Mae Sot formation.

Unit A is composed of shale interbedded with oil shale. The thickness of this unit is 200-800m. There are 4 or 5 thick bed oil shale layers. The quality of oil shale is considered as good grade. The age of Unit A, deposited in Upper Miocene, can be correlated to the middle part of Mae Sot Formation.

The thick bed of oil shale can be found in only unit A and unit C. Unit A is the first priority of oil shale exploration. Unit C is one of the target units in oil shale exploration.



**Figure 4:** Stratigraphy from seismic interpretation

tion. The quality of oil shale in these units varies from medium to high grade. Both of these units were deposited in a lacustrine environment.

101 drill holes covering Mae Sot Basin (60 in Northern area, 23 in Middle area, and 18 in Southern area), indicate that 80% of Mae Sot oil shale has oil content of 12 gallons per ton or 5% by weight (DMF, 2007).

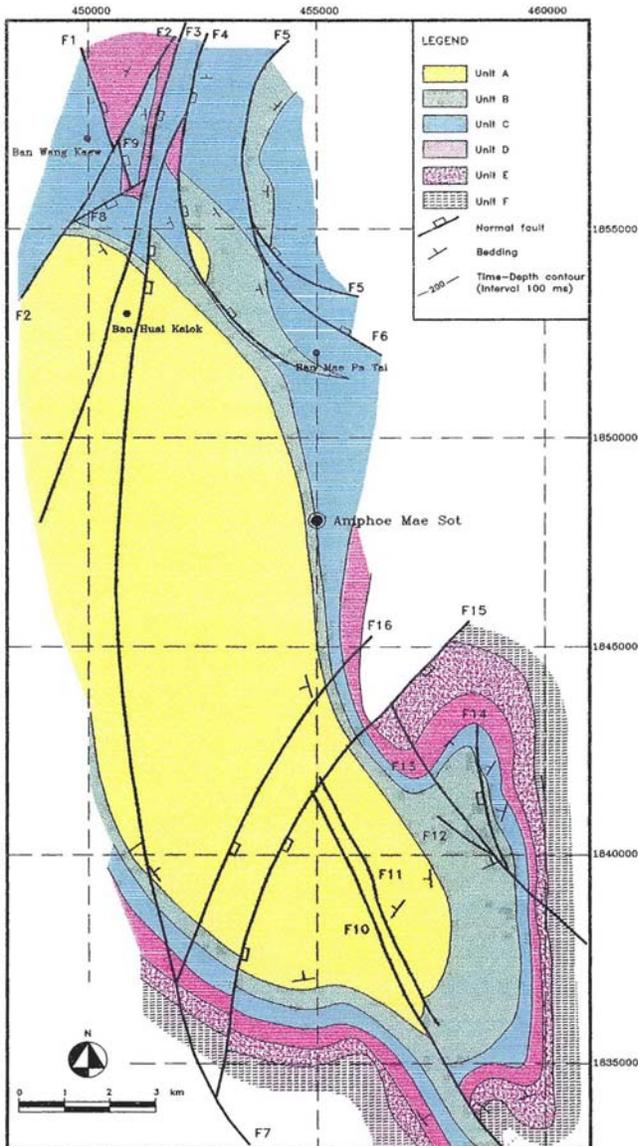
The oil shale layer in the northern sub-basin is shallower than the oil shale layer in southern sub-basin. Moreover, the thickness of oil shale layer in the northern sub-basin is thicker and more continuous than the southern one. The distribution of oil shale area in the northern sub-basin is broader than in the southern sub-basin. The potential yield of oil in the northern sub-basin is also higher than the southern sub-basin. In the northern area within condition of 7.35 gallons per ton oil yield cutoff, the average of oil yield in the northern area is about 14.04 gallons per ton. The stripping ratio is about 9.46. The oil shale thickness varies widely from 3m to 29m, with an average thickness approximately 11m (DMR, 1997).

### Reserves

From the total of 166 drill holes of Mae Sot Basin, reserves of oil shale can be estimated by USGS Cir 891 method with radius of circle area around each drill hole at 200 and 400 meters. Different radius will represent different reserve level types: 200m radius represents Measured reserve, about 952.38 million tons, and of oil extracted from oil shale about 7,680.13 million gallons or 182.86 million barrels. 400m radius represents Demonstrated reserve, about 3,295 million tons, and of oil extracted from oil shale about 26,787 million gallons or 637.80 million barrels (Table 1) (DMR, 1997).

### Quality

The organic matter of Mae Sot oil shale source is composed of Exinite kerogen. The common one is Alginite, which may be the important source of hydrocarbons. Alginite B, an important source of hydrocarbon (Cook and Sherwood, 1981), originates from plankton or benthonic algae. Besides Alginite B, Alginite A and other organic matter such as Resinite, Sporinite and Humic are also found in kerogen. Some



**Figure 5** Tertiary Subsurface Geological Map of Mae Sot Basin

Vitrinite (Huminites) can be found in organic matter.

Mae Sot oil shale is classified into 4 grades depending on the oil content (Hendrickson, 1975). They are (1) Low-grade oil shale, (2) Middle-grade oil shale, (3) Good-grade oil shale, and (4) High-grade oil shale. The oil content of each grade of Mae Sot oil shale is shown in Table 2. The quality of Mae Sot oil shale

varies from low grade to high grade (Thanomsap and Sitahirun, 1992). The shale oil content varies from 1-26% by weight or about 2.5–62 gallons per ton. The average oil content is about 5% by weight or 12 gallons per ton (DMR, 1997).

The properties of Mae Sot oil shale are shown in Table 3. The quantity of moisture is low to high, 0.9–7.6 %; the volatile matter is 24.6–96.5%; spent shale is quite high, 61.10–93.80 %, and sulfur is low, 0.6–1.3%.

From ash analysis, the major components of inorganic matter in Mae Sot Basin are silica and carbonate mineral. The silicate minerals include quartz, potassium feldspar, clay mineral, etc. The major carbonate minerals are calcite and dolomite. Consequently, the compositions of ash are silica (SiO<sub>2</sub>), calcium oxide (CaO), alumina (Al<sub>2</sub>O<sub>3</sub>) and other inorganic matter as shown in Table 4 (DMF, 2007). It also contains manganese, phosphate, and sulphide.

Higher grade oil shale is significantly enriched in silicate minerals (quartz, feldspars, clays, and analcite) relative to carbonates, and in dolomite relative to calcite (Gibling et al., 1985). Seismic interpretation and drilling hole evaluation show a potential area of Mae Sot Basin located in Northern part of Basin, above Ban Hual Kaloke. Average of oil yield is more than 5 gallons per ton. The overburden varies between 0-30m. Thickness of oil shale bedding varies between 2-50m.

**Table 1:** Reserve of Mae Sot oil shale estimated by USGS Cir 891

Reserve of Mae Sot oil shale	Oil shale	Oil Yield	
	Million tons	Million Gallons	Million Barrel
Measured (Radius of 200 meters)	952.38	7,680.13	182.86
Demonstrated (Radius of 400 meters)	3925.41	26787.18	637.79

**Table 2** Quality of Mae Sot oil shale

Grade of oil shale	Oil yield	
	gallons/ton	% by weight
Low-grade oil shale	10	4
Middle-grade oil shale	27	10
Good-grade oil shale	36	14
High-grade oil shale	62	24

**Table 3** General properties of Mae Sot oil shale

Properties	Wt%
Moisture	0.9 – 7.6 %
Volatile	24.6 – 96.5 %
Heat capacity	700 - 4,000 cal/g
Sulfur	0.60 – 1.3 %
Spent shale	66– 94 %
Ash	56– 70.00 %
Gravity	1.60 – 2.10

**Table 4** Ash properties of Mae Sot oil shale

Ash Analysis	Wt%
SiO <sub>2</sub>	38
Al <sub>2</sub> O <sub>3</sub>	13
Fe <sub>2</sub> O <sub>3</sub>	5
CaO	23
MgO	7
Others	14

*Future plan for oil shale development*

Oil shale has been explored again after exploration was delayed for a long time due to the unfavourable economy. In the present time, the Government is reconsidering oil shale development. There is cooperation among Government agencies including Department of Mineral Resources, Department of Mineral Fuel and Electricity Gener-

ating Authority of Thailand, to conduct a possibility study on the use of Mae Sot oil shale as fuel for power generation.

*Conclusion*

The measured reserve of Mae Sot oil shale is 952.38 million tons and oil yield is 182.85 barrels. Quality of Mae Sot oil shale varies from low grade to high grade. The thickness and conformity layer of oil shale in Northern area are better than Southern area. The depth of oil shale in the Northern area is shallower than the Southern area. The potential area is at above Ban Huai Kaloke.

*Acknowledgement*

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